IMAGE PROCESSING APPLICATIONS : AN OVERVIEW

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Abstract

Improved methods of image display, transmission, enhancement, and archiving are of increasing importance to medical scientists and practitioners. The dynamic range of computed tomographic imaging fostered widespread interest among radiologists with respect to the clinical contributions of other digital imaging modalities. The application of digital imaging techniques in pathology also promises to show continued growth because of the high image content of that specialty. Newer methods of image display offer improved three dimensional visualization of anatomic structures; such techniques will find increasing use in teaching anatomy and in surgical planning. The papers at this session will present new applications of image processing techniques. The similarity of issues in image processing across medical specialty boundaries is stressed.

Introduction

The past few years have seen an increased emphasis in the medical literature on research concerning the processing, communicating, displaying, and archiving of images. Since much of the literature and methods have focused on images which are digital when generated (computed tomographic images, for examples) or analog images which are first captured on film and then digitized (e.g., teleradiology), the related issues of optimum pixel matrix density and compression of data have also been of major concern in the literature. Interest in these topics extends across all medical specialties.

Applications in Radiology

In radiology much of the impetus and interest in digital images came with the introduction of computed tomography (CT). Radiologists quickly saw the advantages associated with the ability to manipulate images throughout the dynamic range this modality provided. Portions of the CT image which were of clinical interest could be emphasized through selection of appropriate window and level settings or through magnification. Those portions of the image which were not felt to be important clinically could be deemphasized.

Throughout the history of radiology, most information about a patient has been recorded primarily on film. Large film file rooms, the competing needs for a study or film jacket (radiologist vs specialist in operating room vs referring physician vs house officer vs researcher, for example), and lost or borrowed films are common manifestations of the usual film based system. These and other film management issues together with the desire to preserve the entire dynamic range of information offered by digital imaging modalities such as CT have provided opportunities for the introduction of new technology into systems of medical care.

Although the great majority of imaging procedures performed at this time is not digital [1], there is a strong feeling among many radiologists that it is only a question of time before all radiologic information is digitized [2,3]. Several studies show promise for digital radiography, compared to traditional radiography. Much of the research has focused on chest radiography which comprises the largest single category of radiological procedures performed.

Fraser et al [4] compared interpretations of digital chest images on a cathode ray tube with those obtained with conventional chest radiographs. Although they recognize certain limitations to their study, they concluded that anatomic structures in the mediastinum were better seen on digital images. With minor exceptions, however, no significant differences in pathologic states were identified. User acceptance of the digital system was high. Other studies have had similar results [5] although some have been less than successful in demonstrating advantages for digital radiography [6].

Because of the expense and difficulty involved in converting existing departments to an all electronic format (filmless radiology), some authors propose the use of film-based digital imaging [7]. Arenson et al [8] and Bergey et al [9] describe the picture archiving and communication system at the Hospital of the University of Pennsylvania (HUP). Although approximately 80% of the images in the Department of Radiology at

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HUP are still captured initially on X-ray film, the film-based images are converted into digital form with an Eikonix scanning camera. High density storage systems are continually being improved to address storage requirements for digital images [10,11].

Transmission of images electronically with display at locations in the radiology department or outside it will facilitate comparison and interpretation of images and correlation with other clinically important information. A research project sponsered jointly by the U.S. Public Health Service and the Department of Defense investigated the feasibility of transmitting images digitized in a 512^2 pixel matrix density for remote interpretation in a field trial conducted in 1982. The accuracy of interpretation of the digitized images was statistically significantly less than the accuracy of interpretations using the original film [12]. A new field trial is underway to establish the diagnostic accuracy of transmitted images digitized in a 1024^2 pixel matrix density. The effect of data compression on accuracy will also be studied. In addition, comparison of the original field trial interpretations will be made with interpretations of the films digitized under laboratory conditions in the 1024^2 and processed 512^2 matrix densities. The laboratory study will also use films from the American College of Radiology/Bureau of Radiological Health Learning File to address the issue of accuracy in interpretation at two matrix densities. Determination of the pixel matrix densities needed for accurate interpretation of images is important because use of a matrix density higher than necessary will result in wasted dollars and time. Too low a matrix density may result in unacceptable inaccuracy in interpretation.

Two papers in this session discuss image processing topics related primarily to radiology. The systems described are very different with respect to the types of images used, services provided, geographic areas involved, and computer sophistication required. In the paper "CT Image Processing Using Digital Networks," Rhodes et al describe a service which uses a commercial digital network to connect the computers at 50 CT scanner sites which are widely separated geographically. The host computer provides several processing options, including the generation of reformatted images in various planes. Issues of image transmission, data compression, distributed processing, software maintenance, and interfacility communication are discussed. The authors report that the system has been easy to update from a software point of view and has been extremely reliable.

The paper "Image Processing Natural Quality X-Ray Images in a Small Office Environment" by Rigterink and Rigterink describes three systems which use closed circuit television to make increased use of the information that can be derived from plain film radiography. The three systems represent varying levels of sophistication and the authors describe problems associated with off the shelf hardware currently available.

Applications in Pathology

Pathology is another specialty which is image oriented and which has a large volume of images that need to be interpreted and stored. There are often needs for consultation from pathologists at remote locations so that transmission of images draws another parallel with radiology practice. Consequently, many of the issues stated above with respect to radiology are germane to pathology. These include pixel matrix density, data compression, networking, and high density storage.

Beltrame et al describe the formation of digital holograms of human cells using a microscope, television camera, A/D conversion, and fast storage. A computer and reconstruction algorithm have been designed to produce three dimensional images [13].

At this session Okagaki et al and Tzou et al describe a system which digitizes and processes images formed by a scanning transmission electron microscope. They discuss pixel density, image compression, and image enhancement issues for this system and describe parallels to the development of picture archiving and communication systems in radiology. The authors used a pixel density of $(1K)^2$ in their research but conclude that pixel densities of $(2K)^2$ or $(4K)^2$ are more desirable.

Other Clinical Applications

In addition to radiology and pathology, other clinical specialties are concerned with image acquisition and storage. Cambier et al described a system for video acquisition, storage, and processing of fluorescein angiograms obtained during ophtholomological evaluation [14]. They investigated various line resolutions and concluded that the system must provide resolution in the area of the macula equivalent to approximately 1080 x 1320 pixels over a 35mm slide.

In this session, Meals and Kabo describe a method of using computer graphics to teach musculoskeletal anatomy. Parallel transverse cuts are made through a fresh limb specimen at three millimeter intervals. The block's face is photographed and slides are prepared on a digitizing tablet. The anatomical information is manually digitized as a series of closed contours and entered into computer storage. The system can display images which can be manipulated with respect to size, orientation, and other characteristics. The authors propose use of such techniques by surgeons to simulate operative procedures.

Conclusions

Processing of images is important throughout the range of clinical practice. Questions of optimal resolution for interpretation, data compression, transmission, enhancement, and storage of images are issues which are not limited to any one medical specialty. It is likely that PACS developments in one specialty will benefit others.

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